

Large Scale Data Visualization and Rendering: Scalable Rendering

Randall Frank

Lawrence Livermore National Laboratory



UCRL-PRES-145218

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Definitions and Goals (1)

- **Scalable rendering definition**

For an increase in work quanta, an equivalent increase in rendering resources maintains constant rendering time.

- **The Goal: Aggregation**

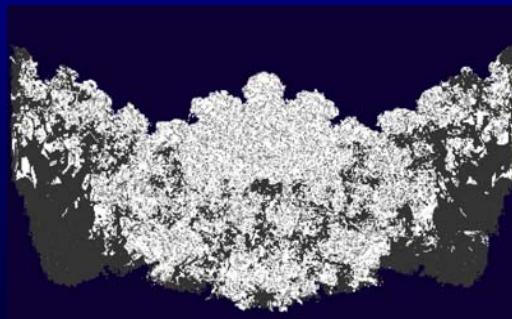
The basic scalable rendering goal is to effectively and efficiently aggregate various system components to address increasing data driven demands.

Definitions and Goals (2)

- **Visualization scalability along two axis**

- Datasets
 - Increases in cell count, etc.

- Displays
 - Higher pixel counts
 - Multiple/tiled displays



LLNL ASCI White
(8192 CPUs, 13TF)

469M Triangle Isosurface
(2048x2048x1920x273 Grid)



IBM T221 'Bertha' (3840x2400)



LLNL PowerWall (6400x3072)

What makes rendering unique?

Generation of graphical primitives

- Graphics computation: primitive extraction/computation
- Multiple rendering engines (both in number and type)

Video displays

- Routing of video tiles
- An aggregation of multiple rendering engines

Interactivity (not a render-farm!)

- Real-time imagery
- Interaction devices, human in the loop (prediction issues)

Unique I/O requirements

- Access patterns/performance

Systems Architecture

What does a scalable rendering system look like?

One or more systems/machines providing:

- Computational capacity (extract primitives)
- Graphical rendering capacity (draw primitives)
- Display capacity (display images)

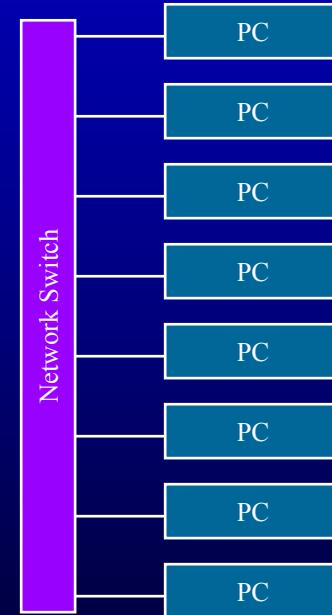
Layered, integrated software:

- Application (domain/problem specific)
- Toolkits, Data models, etc
- Rendering (Mesa, OpenGL, DirectX, Qsplat, etc)

System Architecture: Compute Nodes

Computational elements upon which the visualization application runs

- May run the computation itself!
- **Single system image (SSI)**
 - SGI Onyx
- **Distributed clusters**
 - IBM SP, Myrinet+PCs
- **I/O systems**
 - “Interconnect”
 - NUMA, Myrinet, GigE, ...
 - Disk subsystems



System Architecture: Graphics Options

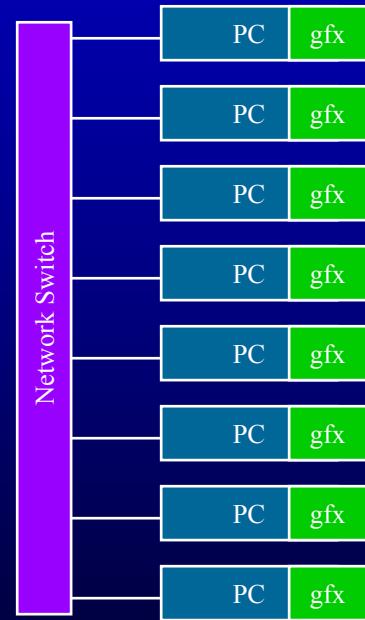
Add rendering capability to the nodes

- **Software**

- Mesa
- Custom (e.g. qsplat)

- **Hardware**

- IR pipes/pipelinelets
- PC graphics
 - nVidia, Matrox, ...
 - 3Dlabs, HP, ...

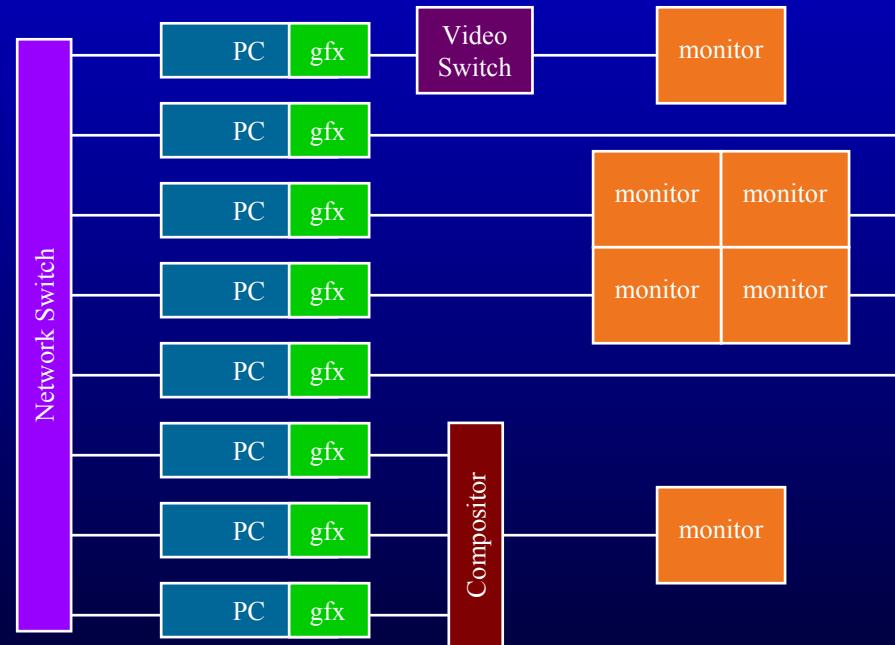


nVidia GeForce 2

System Architecture: Displays

Connect rendering capability to displays

- Desktop(s)
- Tiled displays
 - PowerWalls
 - IBM T221 ("Bertha")
- Video switching
- Video delivery
- Custom hardware
 - IBM SGE
 - Stanford Lightning-2
 - Compaq Sepia-2
 - SGI, HP video compositors



Systems Architecture: Software

Various goals result in very different software solutions...

Must provide an appropriate solution to the aggregation problem.

A balance must be struck between data handling and rendering requirements.

Rendering Aggregation Approaches

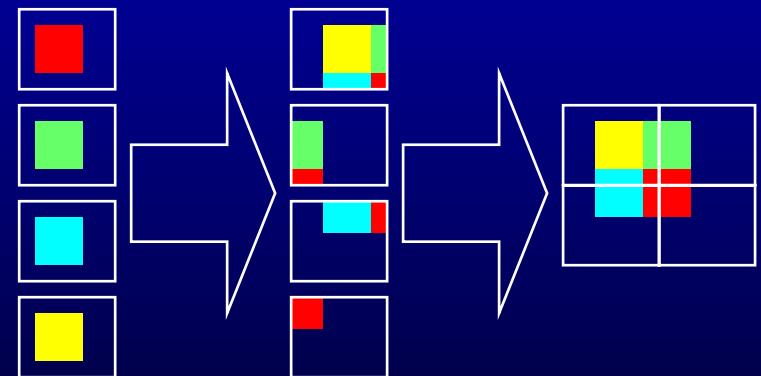
- **2D - “screen space”**
 - “Sort-first” rendering model
 - Targets display scalability
 - Supports high frame rates
- **3D - “data space”**
 - “Sort-last” rendering model
 - Targets large data scalability
 - Supports high primitive counts

Aggregation: Sort First

Tiling (2D decomposition in screen space)

Route portions of a final aggregate display to their final destination with no overlap

- Order independent
- Destination determines bandwidth
- Graphics primitives may be moved, replicated or sorted for load balancing
- Simple color data
- Can support local framerate

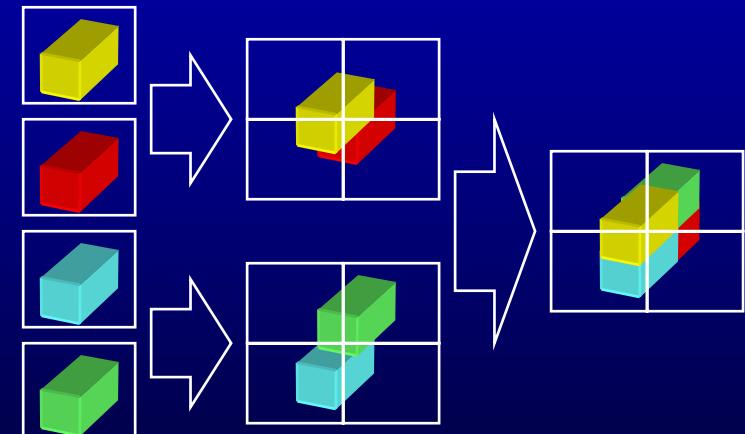


Aggregation: Sort Last

Compositing (3D decomposition in data space)

3D blocks that are combined using classic graphics operators (e.g. Z-buffering, alpha blending, etc)

- Z, α , stencil enhanced pixels
- Fixed 3D data decompositions (data need not move)
- Bandwidth exceeds that of output display (3D vs 2D)
- Hierarchy trades bandwidth for latency
- Ordering may be critical
- “Generation” at local framerate



Aggregation: Issues

- Multi-pass rendering algorithms
 - “Complete” intermediate image requirements difficult
- Framebuffer readback
 - Performance and availability of graphics APIs
- Rendering resolution issues
 - Dataset domains and (global) Z-buffer resolution
 - Limited pixel resolution (e.g. α -compositing)
- Compositing Issues
 - Latency and ultimate framerate
 - Ordering/Transparency
- Flexible/scalable software interfaces
 - Data partitioning: The “zoom” problem
 - Anisotropic rendering environments

Examples: Scalable Rendering Systems

Hardware

- Classical SSI and clusters (SGI, IBM, etc)
- “Viz Sim” cluster systems (SGI, HP, Artabel)
 - Limited data (replicated), targets walls/”immersion”

Software

- Integrated application/framework solutions
 - VTK, OpenDX (MPI), EnSight, MeshTV, VisIt
- “Low-level” toolkits
 - libpglc, TNT-Pmesa, WireGL, Chromium

Examples: Sort-last Toolkits

- **TNT-PMesa (Sandia, Lisa Ice, et al)**
 - Composition system integrated into Mesa
 - Details of the scheme hidden behind OpenGL API
 - Linked to software rasterizer (Mesa)
 - Not the SourceForge PMesa project!
- **Libpglc (Sandia, Brian Wylie, et al)**
 - Sort-last composition, several optimized modes
 - New application API/rendering structure
 - Supports hardware rendering
 - 300M Polys/sec @ 64 nodes on a 469M tri isosurface

Examples: WireGL Toolkit (1)

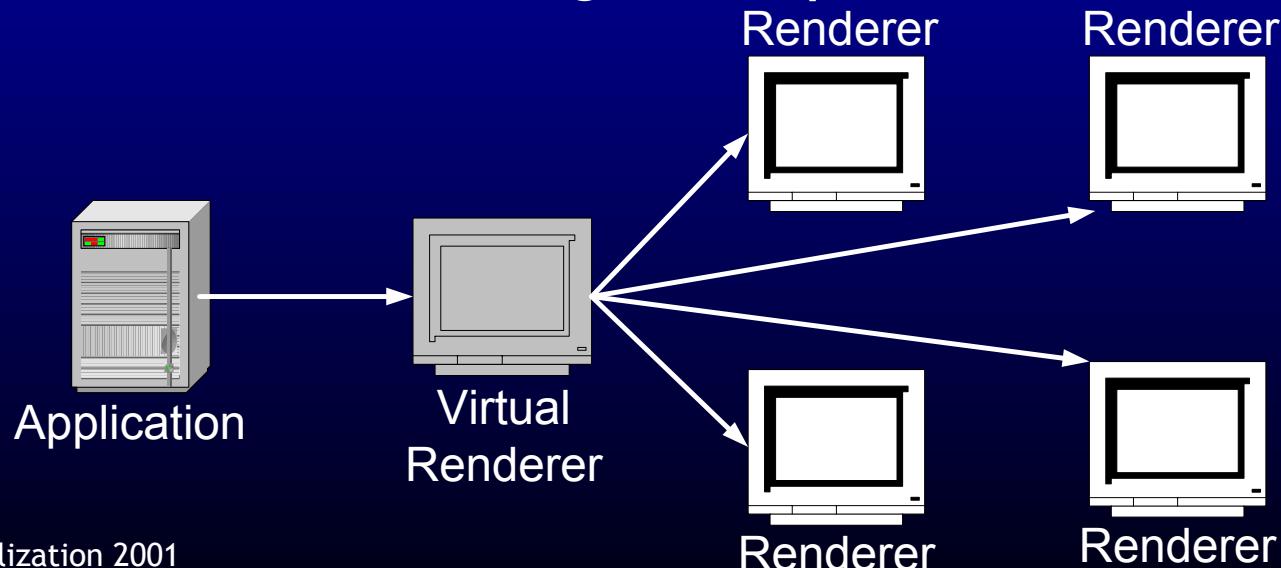


“Drop-in” replacement for OpenGL (Stanford)

- Supports unmodified applications

Targets tiled displays

- Geometry bucketed/sorted
- “Sort-first” routing of all primitives



Examples: WireGL Toolkit (2)



Efficient network protocol

- All OpenGL commands encoded onto a stream
- Rendering on remote “servers”
- Context state tracking

Parallel OpenGL API

- Semaphores/Barriers
- “Handled” in the servers

Demonstrated input and output scalability

- Many noted limits, so...

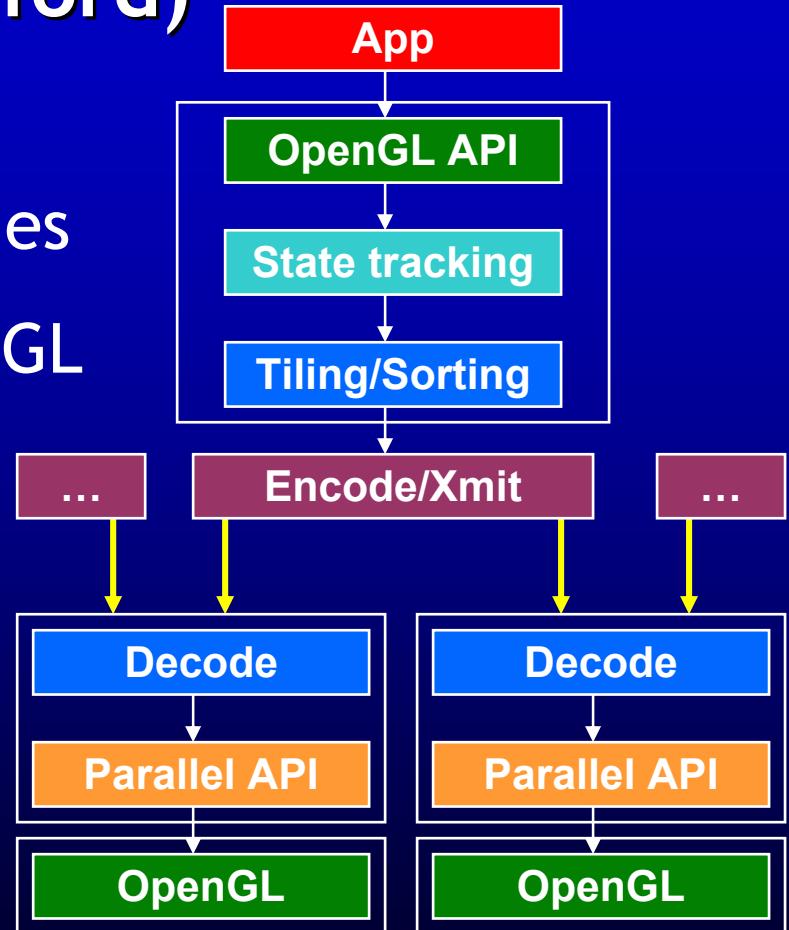
Examples: Chromium Toolkit (1)

WireGL replacement (Stanford)

- Work-in-progress
- Based on WireGL technologies
- Chromium implements WireGL

Addressing limitations

- “Local” node rendering
- Extensibility
- Non-render/tile operations
- Better hardware abstractions



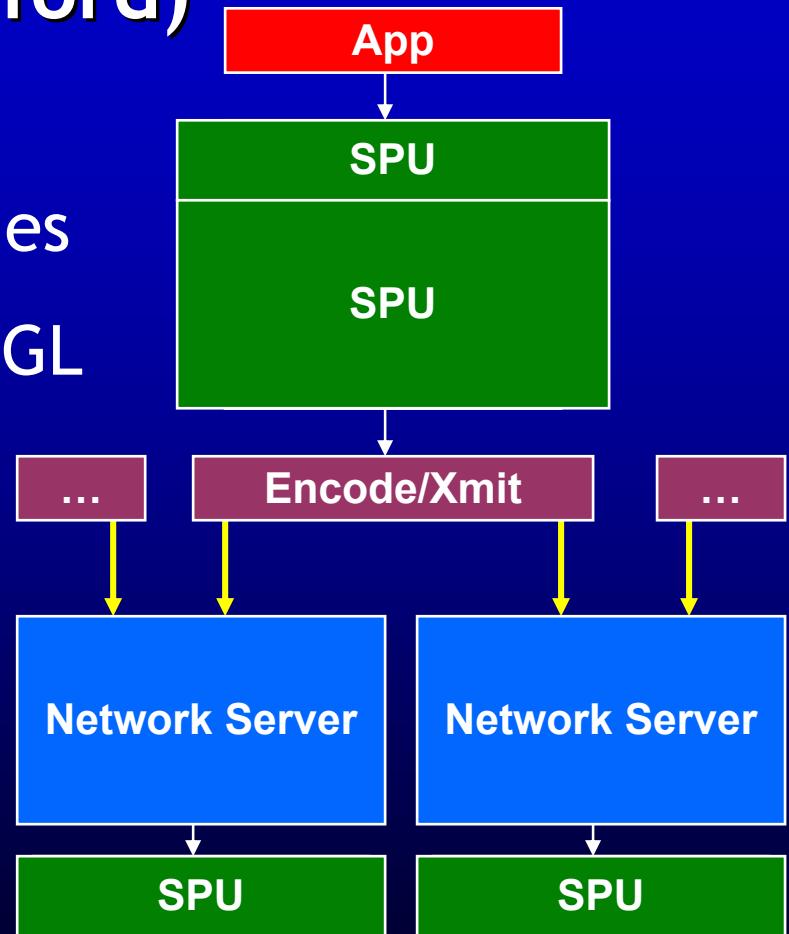
Examples: Chromium Toolkit (1)

WireGL replacement (Stanford)

- Work-in-progress
- Based on WireGL technologies
- Chromium implements WireGL

Addressing limitations

- ‘Local’ rendering (sort-last)
- Extensibility
- Non-render/tile operations
- Better hardware abstractions



Examples: Chromium Toolkit (2)

Distributed rendering pipeline management system

- Hinting/query interfaces (application “translucent”)

Extensibility: The Stream Processing Unit (SPU)

- “Filter” view of an OpenGL implementation
- Allow for direct OpenGL rendering (e.g. sort last)
- True rendering framework for algorithm integration
- Any SPU can render, modify, absorb... the OpenGL API
- Supports SPU inheritance

Improved context handling

- Multiple contexts/application windowed contexts

Examples: Compositing Systems

Custom hardware for image composition

- **Sepia (Compaq)**
 - Dedicated network (ServerNet II)
 - Custom compositing (FPGA on NIC)
- **Lightning-2/MetaBuffer (Stanford & Intel/UTexas)**
 - DVI based tiling/compositing
- **Scalable Graphics Engine (IBM)**
 - “Tiled” framebuffer
 - gigE/UDP based



Sepia-2



Lightning-2

Present and Future...

Basic and partial solutions available today...

- Turnkey tiled display and cluster aware applications
- Integrated data and rendering ‘toolkits’

Still many research and development topics

- Improved compositing (HW and SW solutions)
- Data representations/decompositions
- Alternate visualization approaches
 - Multi-resolution/progressive techniques
 - New primitives/rendering methods

Some Library/Application Links

Mesa: mesa3d.sourceforge.net

TNT-PMesa: www.cs.sandia.gov/VIS/pmesa.html

WireGL: graphics.stanford.edu/software/wiregl

Chromium: chromium.sourceforge.net

VTK: www.kitware.com

OpenDX: www.opendx.org

EnSight: www.ceintl.com

MeshTV: www.llnl.gov/meshtv